

OPTICAL SPECTROSCOPY OF CANDIDATES FOR QUASARS AT $3 < z < 5.5$ FROM THE XMM-NEWTON X-RAY SURVEY. A DISTANT X-RAY QUASAR AT $z=5.08$

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We present the results of optical spectroscopy for 19 quasar candidates at photometric redshifts $z_{\text{phot}} \gtrsim 3$, 18 of which enter into the Khorunzhev et al. (2016) catalog (K16). This is a catalog of quasar candidates and known type 1 quasars selected among the X-ray sources of the *3XMM-DR4* catalog of the XMM-Newton serendipitous survey. We have performed spectroscopy for a quasi-random sample of new candidates at the 1.6-m AZT-33IK telescope of the Sayan Solar Observatory and the 6-m BTA telescope of the Special Astrophysical Observatory. The spectra at AZT-33IK were taken with the new low- and medium-resolution ADAM spectrograph that was produced and installed on the telescope in 2015. Fourteen of the 18 candidates actually have turned out to be quasars; 10 of them are at spectroscopic redshifts $z_{\text{spec}} > 3$. The high purity of the sample of new candidates suggests that the purity of the entire K16 catalog of quasars is probably 70–80%. One of the most distant ($z_{\text{spec}} = 5.08$) optically bright ($i' \lesssim 21$) quasars ever detected in X-ray surveys has been discovered.

Keywords: active galactic nuclei, X-ray surveys, photometric redshifts, spectroscopy, XMM-Newton.

1. INTRODUCTION

Searching for quasars at $z \gtrsim 3$ is one of the most important elements of studying the growth history of supermassive black holes and the evolution of massive galaxies in the Universe. To construct the X-ray luminosity function for quasars at $z \gtrsim 3$ requires collecting a large and well-defined X-ray sample of such objects with fluxes $\lesssim 10^{-14}$ erg s^{−1}cm^{−2} (0.5–2 keV).

The number of sources in the deep *XMM-Newton* and *Chandra* X-ray surveys (typical fluxes $\lesssim 10^{-15}$ erg/s/cm² in the 0.5–2 keV energy band and areas of ~ 1 sq. deg.) turns out to be insufficient to trace in detail the evolution of active galactic nuclei (Civano et al., 2012; Vito et al., 2014). Through the addition of data from the less deep *XBootes*, *XMM-XXL* X-ray surveys (typical 0.5–2 keV fluxes $\sim 10^{-14}$ erg/s/cm²) the sky coverage area increases by a factor of ~ 10 (Ueda et al., 2014; Aird et al., 2015; Georgakakis et al., 2015). In their recent Kalfountzou et al. (2014) paper constructed the X-ray luminosity function for quasars at $z > 3$ in

a field $\simeq 33$ sq. deg. The survey of such a field was composed of the archival data from individual pointings of the *Chandra* satellite over the entire time of its operation. (Kalfountzou et al., 2014) managed to exclude some models of the luminosity function using the survey data, but the size of this sample turns out to be insufficient to investigate the properties of the population of bright (luminosities $> 5 \times 10^{44}$ erg/s) and distant ($z > 3.5$) quasars.

The data from the *XMM-Newton* X-ray telescope accumulated over 15 years represent a serendipitous X-ray sky survey (Watson et al., 2009) with a total area of ~ 800 sq. deg. and a sensitivity $\approx 5 \times 10^{-15}$ erg s^{−1}cm^{−2} (the *3XMM-DR4* version¹, Watson et al., 2009). A sample of quasars at $z > 3$ selected by their X-ray emission that exceeds the existing samples of Kalfountzou et al. (2014); Georgakakis et al. (2015) by several times can be obtained from the data of this survey.

Previously (Khorunzhev et al., 2016), we made an attempt to find new sources and to obtain a more

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¹<http://heasarc.gsfc.nasa.gov/W3Browse/xmm-newton/xmmssc.html>

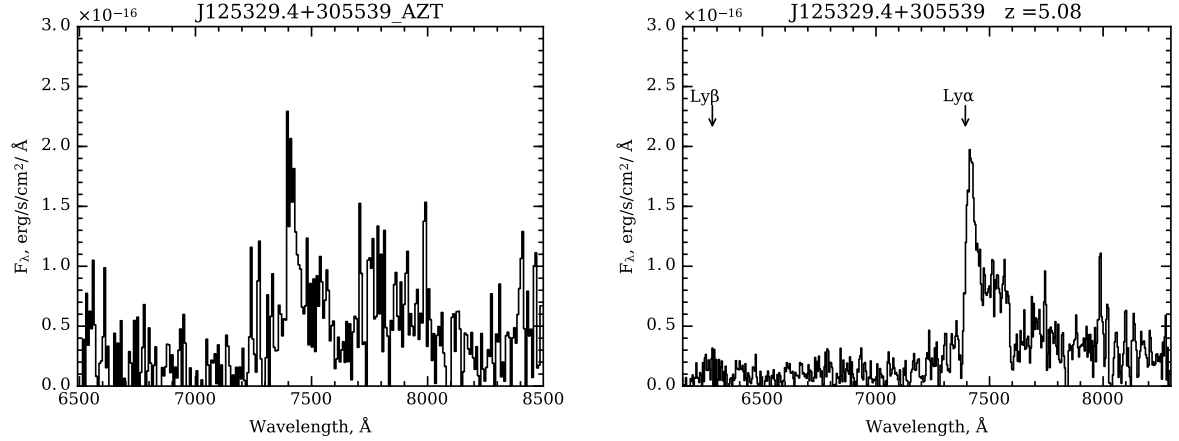


Fig. 1: Spectra of the distant quasar *3XMM J125329.4+305539* ($z_{\text{spec}} = 5.08$) taken at the 1.6-m AZT-33IK telescope (left) and the 6-m BTA telescope (right). The neighboring spectral channels are binned by two along the wavelength axis.

complete sample of X-ray quasars at $z > 3$ in the fields of the serendipitous *XMM-Newton 3XMM-DR4* survey at Galactic latitudes $|b| > 20^\circ$ using photometric data from the Sloan Digital Sky Survey (*SDSS*, Alam et al., 2015), *2MASS* (Cutri et al., 2003) and *WISE* (Wright et al., 2010). The area of the overlap between *3XMM-DR4* and *SDSS* is ~ 300 sq. deg. Based on the broadband photometry of the above surveys, we obtained the photometric redshift estimates (z_{phot}) using the *EAZY* software (Brammer et al., 2008). We compiled a catalog of 903 candidates for distant quasars selected by the photometric redshift (*K16*). Both already known quasars (with spectroscopic redshifts $z_{\text{spec}} > 3$) and new unstudied objects (with photometric redshift estimates $z_{\text{phot}} > 2.75$) enter into the catalog.

The completeness of *K16* in the investigated fields relative to the spectroscopic catalogs of quasars (*SDSS* (Alam et al., 2015) and *The Half Million Quasars* (Flesch, 2015)) with $z_{\text{spec}} > 3$ is about 80%. The normalized median absolute deviation ($\Delta z = |z_{\text{spec}} - z_{\text{phot}}|$) is $\sigma_{\Delta z / (1 + z_{\text{spec}})} = 0.07$, while the outlier fraction is $\eta = 9\%$ (when $\Delta z / (1 + z_{\text{spec}}) > 0.2$).

In the *K16* catalog about 40% of the candidates have no spectroscopic redshifts. These are new quasar candidates. If most of them are actually quasars at $z > 3$, then the existing *3XMM-DR4* sample of distant quasars can be expanded by a factor of ~ 1.5 (Khorunzhev et al., 2016). Spectroscopic verification is needed to understand the accuracy of the z_{phot} estimate and to estimate the purity of the selection of quasar candidates. Obtaining the spectra of several hundred objects

“scattered” over the celestial sphere is a laborious task. However, we can take the spectra of a small “random” sample and draw preliminary conclusions about the quality of the z_{phot} estimates for new sources based on them. We prepared a program of observations of candidates for distant quasars at $3 < z < 5.5$ from the *K16* catalog at the 1.6-m AZT-33IK and 6-m BTA telescopes. By now the spectra of 18 objects have been taken as part of the program. Below we present the results obtained from these data.

2. OBSERVATIONS AT THE AZT-33IK TELESCOPE WITH THE LOW- AND MEDIUM-RESOLUTION ADAM SPECTROGRAPH

A quasi-random spectroscopic survey of 18 quasar candidates from the *K16* catalog that previously had no spectroscopic redshifts has been conducted at the AZT-33IK telescope (Kamus et al., 2002) equipped with the low- and medium-resolution ADAM spectrograph (Afanasiev et al., 2016; Burenin et al., 2016).

The AZT-33IK telescope is located at the Sayan Solar Observatory of the Institute of Solar–Terrestrial Physics, the Siberian branch of the Russian Academy of Sciences, and has a primary mirror diameter of 1.6 m. The ADAM spectrograph was produced at the Special Astrophysical Observatory and was installed on AZT-33IK in 2015. The main structural components of the spectrograph are: *Andor Newton 920* array with an efficiency of $\sim 90\%$ in the range

from 4000 to 8500Å and a set of dispersive elements (volume phase holographic gratings). The quantum efficiency of the entire system (the telescope mirror, the spectrograph, the grating, and the CCD array) reaches 50% (Burenin et al., 2016).

The target objects of the *K16* sample are quasars with broad emission lines. The typical apparent magnitude of the objects is $i' \sim 20.5$. The exposure time was chosen to be sufficient for the bright emission lines from which the quasar redshift could be determined to manifest themselves. This allows the spectra for quite a few sources to be taken with a small telescope. Spectra with a higher signal-to-noise ratio in continuum are required to determine the redshift and type of sources without bright lines. Repeated observations with a longer exposure time or at larger telescopes are needed for this purpose.

The properties of the *K16* sample change significantly with increasing redshift: the number of objects drops exponentially; the X-ray and optical fluxes become fainter. On average, the *K16* objects are at $z_{\text{spec}} \sim 3$ and have magnitudes $i' \sim 20.5$. There are only a few dozen candidates at $z_{\text{phot}} > 4$ with magnitudes $i' > 20.5$ in the *K16* catalog. We selected the sources for our observations almost randomly within two ranges: $2.75 < z_{\text{phot}} < 4$ and $z_{\text{phot}} \geq 4$. However, in the range $2.75 < z_{\text{phot}} < 4$ we preferentially observed bright candidates with $i' < 20$. These peculiarities of the selection of objects for our spectroscopic program should be taken into account when formulating the conclusions about the purity of the entire *K16* catalog of quasars.

The quasar candidates were observed in dark time (the lunar phase is less than 0.3) and at a mean seeing better than 2-arcsec. Under such conditions, a one-hour exposure time is sufficient for the detection of emission lines in the spectra of quasars with magnitudes $i' = 20.5$. For our observations we used a 2-arcsec-wide slit. The objects at $z_{\text{phot}} < 3.5$, $3.5 < z_{\text{phot}} < 4.5$, $4.5 < z_{\text{phot}}$ were observed with the VPHG600G (the range is 3700–7340Å, the resolution is 8.8Å), VPHG300 (the range is 3900–10500Å, the resolution is 13.8Å), and VPHG600R (the range is 6520–10100Å, the resolution is 7.3Å) gratings, respectively. The above resolutions were achieved for the 2-arcsec-wide slit. We chose such a grating that the presumed position of the Ly α line was near the peak of its diffraction efficiency. The data were reduced with the standard IRAF² software.

²<http://iraf.noao.edu>

3. RESULTS

The list of objects is given in Table 1 (end of this paper, their spectra are shown below in Fig. 3). The shape of the spectra was corrected using the observations of spectrophotometric standards from the list by Massey et al. (1988). Fourteen of the 18 are quasars; 10 of them are quasars at $z_{\text{spec}} > 3$. Their redshifts were determined from the positions of the peaks of broad lines in the spectrum. The types of the remaining objects are difficult to determine, because there are no bright emission lines in their spectra.

The accuracy of the redshift for distant objects depends on the spectrograph resolution as $(1+z) \times \frac{\Delta\lambda}{\lambda}$ and is approximately 0.01 for low-resolution spectra. Therefore, the spectroscopic redshifts for the objects are given to the second decimal place. The shape and positions of broad lines are known to be closely related to the processes occurring near a black hole. The redshift determined from broad lines can slightly differ from z_{spec} of the host galaxy. The redshifts in the spectra where only the Ly α line is seen should be treated with caution. Its shape can be severely distorted by absorption and, consequently, the position of its peak can be determined incorrectly. Such objects are marked by the quality flag (QF) = 1 in Table 1.

The spectroscopic sample of 18 “randomly” selected objects has a median 0.5–2 keV X-ray flux $\simeq 5 \times 10^{-15}$ erg/s/cm². This value coincides with the median X-ray flux of the *K16* sources. Among the selected objects there are no bright quasars with strong emission lines at $z_{\text{spec}} > 3$ with 0.5–2 keV fluxes $> 10^{-14}$ erg/s/cm². The median apparent magnitude is $i' = 19.9$, which is brighter than the mean value for the *K16* by 0.5 magnitude. Thus, the sample of 18 sources may be deemed representative in X-ray flux for the *K16*, but not in optical flux.

3.1. The Quasar 3XMM J125329.4+305539 at $z = 5.08$

The distant X-ray quasar 3XMM J125329.4+305539 at $z_{\text{spec}} = 5.08$ and with an apparent magnitude $i' = 21$ was discovered and confirmed at the AZT-33IK and BTA telescopes. The AZT-33IK and BTA spectra are shown in Fig. 1.

The first spectrum of this object was taken at the AZT-33IK telescope with the ADAM spectrograph with an exposure time of 1.5 h. From the spectrum we managed to determine that the source is a distant quasar and to measure its redshift $z_{\text{spec}} = 5.1$. Telescopes with a larger diameter

are usually required to take the spectra of such sources. However, as can be seen from our results (see Fig. 1), using the new spectrograph with a high quantum efficiency in the near infrared at the 1.6-m AZT-33IK telescope, we can take the spectra of faint objects (down to $i' \simeq 21$), and determine their types and redshifts.

To improve the spectroscopic redshift, we took a spectrum with a higher signal-to-noise ratio and a resolution of 18Å at the 6-m BTA telescope using the SCORPIO spectrograph (Afanasiev & Moiseev, 2005) with an exposure time of 0.5 h. The redshift $z_{\text{spec}} = 5.08 \pm 0.01$ was determined by fitting the spectrum by the template of a type 1 quasar (Vanden Berk et al., 2001) into which the interstellar absorption by neutral hydrogen was introduced (Madau, 1995). The error of the template position is underestimated, because the template is an averaged model of the spectrum that disregards the individual deviations in the spectrum of the separate source. Therefore, the error was estimated via the spectral resolution of the instrument.

3XMM J125329.4+305539 was first reported as a probable quasar at $z_{\text{phot}} = 4.64$ in the *K16* catalog, and there was no information about this source in other photometric catalogs of quasar candidates³. It was not an XMM-Newton target (i.e., it fell within its field of view by chance). Its SDSS apparent magnitude is $i' \simeq 21.0$. The 0.5–2 keV X-ray flux is 1.5×10^{-15} erg/s/cm², the 0.5–2 keV luminosity is 4×10^{44} erg/s in the observer's frame.

Apart from this source, only three optically bright (there is reliable SDSS photometry) X-ray quasars at $z_{\text{spec}} > 5.0$ that were not target objects for pointing *XMM-Newton* are known in the *3XMM-DR4* catalog: *3XMM J221643.9+001346* ($z_{\text{spec}} = 5.01$, $i' \simeq 20.3$) Anderson et al. (2001); Gavignaud et al. (2006), *3XMM J011544.8+001513* ($z_{\text{spec}} = 5.10$, $i' \simeq 21.4$) McGreer (2013), *3XMM J022112.5-034251* ($z_{\text{spec}} = 5.01$, $i' \simeq 19.3$) Paris et al. (2016). The first two sources were found in the *SDSS Stripe 82*, where the *SDSS* sensitivity is much better than that averaged over the sky and, consequently, the selection completeness is higher.

Note that there is one more source in the *K16* catalog, *3XMM J004054.6-091527*, with the published spectroscopic redshift $z_{\text{spec}} = 5.002$ from *SDSS* data release 12 (DR12). However, fresher results of spectroscopy ($z_{\text{spec}} = 4.980 \pm 0.010$) for this source obtained at a telescope with a larger diameter are presented in (Worseck et al., 2014).

³<http://vizier.u-strasbg.fr>

Table 2. Properties of the selected X-ray quasars at $z_{\text{spec}} > 5$.

Name (XMM)	z_{phot}	z_{spec}	i'	F^{-14}	$L_{0.5-2}$
J011544.8+001513	0.61	5.10	21.4	0.19	44.7
J022112.5-034251	4.74	5.01	19.3	0.61	45.2
J125329.4+305539	4.64	5.08	20.9	0.15	44.6
J221643.9+001346	4.91	5.01	20.3	0.22	44.8

Note. z_{phot} is the photometric redshift of the object in the *K16* catalog; z_{spec} is the spectroscopic redshift; i' is the apparent magnitude in the SDSS i' band; F^{-14} is the 0.5–2 keV X-ray flux (erg/s/cm²) normalized to 10^{-14} ; $L_{0.5-2}$ is the common logarithm of the X-ray luminosity (erg/s in 0.5–2 keV in the observer's frame).

Therefore, *3XMM J004054.6-091527* is no longer considered as a quasar at $z_{\text{spec}} > 5.0$.

Thus, the object *3XMM J125329.4+305539* investigated by us is one of the brightest and most distant X-ray quasars at $z_{\text{spec}} > 5.0$ suitable for constructing the X-ray luminosity function at such redshifts. The redshifts, magnitudes, and X-ray fluxes of *3XMM J125329.4+305539* and the other three distant quasars listed above are given in Table 2. Note that there are also even more distant quasars in the *3XMM-DR4* catalog, but they were target sources for pointing the X-ray telescope (after their discovery in the optical band) and, therefore, cannot be used in constructing the X-ray luminosity function.

3.2. Remarks on Individual Objects

3XMM J025459.8+192343. This source ($z_{\text{spec}} = 2.81$) does not enter into the published *K16* catalog, but, nevertheless, it was included in Table 1. Its spectrum was taken on the first nights of ADAM operation, when it was a candidate in the intermediate version of *K16*. We thought that the photometric redshift of the source was $z_{\text{phot}} = 2.6$, and it could theoretically be at $z_{\text{spec}} > 3$. This source enters into the catalog of quasar candidates by (Richards et al., 2015), where its best photometric redshift estimate is 3.295.

3XMM J062923.4+634935. There is a set of narrow absorption lines in the spectrum of this quasar ($z_{\text{spec}} = 2.88$). We assume that the most distinct lines are $\lambda_{H\beta 4861} = 5696\text{Å}$, $\lambda_{MgI 5175} = 6077\text{Å}$, and $\lambda_{NaI 5891} = 6895\text{Å}$. A cloud of intergalactic gas that gives such a line structure probably lies on the line of sight between us and the object (at $z_{\text{spec}} \simeq 0.17$).

3XMM J103901.4+643335. This is a distant quasar at $z_{\text{spec}} = 4.08$. It is located in the region of the overlap between the *XMM-Newton* and

Chandra surveys. Both telescope detected an X-ray flux from this source. The source was first reported as a quasar candidate in the *K16* with $z_{\text{phot}} = 4.01$. There are only a few dozen known X-ray quasars at $z_{\text{spec}} \sim 4$. Therefore, the confirmation of this source has a high significance for studying the the population of quasars at such redshifts.

3XMM J131213.0+352347. This source has $z_{\text{phot}} = 4.92$. Feature characteristic of M-type stars are seen against the background of big noise in the spectrum.

Additional Remarks to the K16 Catalog

After the publication of the K16 catalog, having additionally browsed the literature, we found that two X-ray sources, 3XMM J122004.8+291304 and 3XMM J172014.1+264712, were erroneously included in the K16 catalog as quasar candidates. These X-ray sources turned out to be objects of the nearby Universe.

3XMM J122004.8+291304. This is a globular cluster in the halo of the nearby galaxy NGC 4278 (*NGC 4278-X30* or *CXO J122005.011+291304.73* (Liu, 2011; Usher et al., 2012)).

3XMM J172014.1+264712. The source is the cluster galaxy *RX J1720.1+2638* at $z = 0.338$ (Owers et al., 2011).

This information is included in Table 1.

3.4. Purity of the Quasi-Random Spectroscopic Sample and the K16 Catalog

We determined the spectroscopic redshifts of the 18 quasar candidates selected quasi-randomly from the *K16* catalog. Let us estimate the purity of this sample in wide ranges of photometric redshifts: $2.75 \leq z_{\text{phot}} < 4$, $4 \leq z_{\text{phot}} < 5$, $5 \leq z_{\text{phot}} < 5.5$. By the purity we mean the ratio of the number of true quasars ($|z_{\text{phot}} - z_{\text{spec}}|/(1 + z_{\text{spec}}) < 0.2$) to the number of all objects with the available spectra. The condition $|z_{\text{phot}} - z_{\text{spec}}|/(1 + z_{\text{spec}}) < 0.2$ is introduced to take into account the scatter of z_{phot} relative to z_{spec} . A value of 0.2 roughly corresponds to three standard deviations of z_{phot} relative to z_{spec} for all of the known and spectroscopically confirmed quasars from the complete *K16* catalog (see Khorunzhev et al. (2016)). The purity of the spectroscopic sample of 18 objects calculated in this way is shown in Fig. 2 (circles).

For comparison, the arrows in Fig. 2 indicate the lower limit for the purity of the entire *K16* catalog (without the AZT-33IK observations). This limit was deduced as the ratio of the number of true quasars with known spectroscopic redshifts and $|z_{\text{phot}} - z_{\text{spec}}|/(1 + z_{\text{spec}}) < 0.2$ to the total

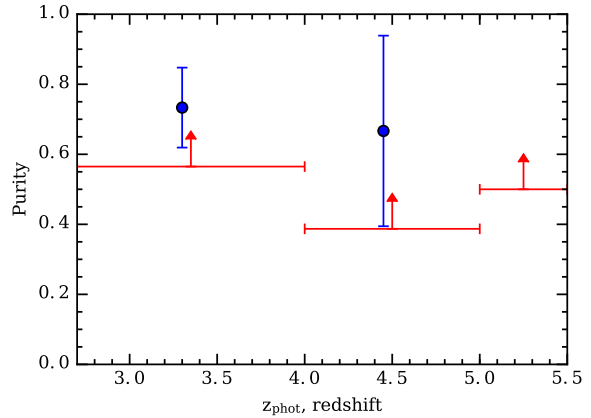


Fig. 2: The circles with Poissonian errors indicate the purity of the 18 quasar candidates whose spectra were taken at AZT-33IK. The arrows indicate the estimated lower limit for the purity of the *K16* catalog relative to the objects with known (from literature or SDSS) spectroscopic redshifts.

number of objects in the catalog. Recall that the candidate sources without spectroscopic redshifts accounted for about 40% of the *K16* objects.

Since the purity of the *K16* catalog was initially higher than 50% and since more than half of the 18 objects with optical AZT-33IK spectroscopy turned out to be quasars at $z_{\text{spec}} > 3$, we can draw the preliminary conclusion that the true purity of the K16 catalog of candidates for distant quasars is 70–80%. This conclusion is yet to be refined, because the sample for our observations at the AZT-33IK telescope was not absolutely random and consisted of relatively bright (for the *K16*) objects.

4. CONCLUSIONS

In this paper we showed that the purity of the quasi-random sample of 18 quasar candidates from the *K16* catalog exceeds 50%. Strictly speaking, this is true only for optically bright sources, $i' \lesssim 20$. We are going to continue the spectroscopy of candidates from the K16 sample with the ADAM spectrograph at the AZT-33IK telescope. However, a telescope with a larger diameter will be required to check the bulk of the *K16* objects ($i' \sim 20.5$, $z_{\text{phot}} \sim 3$). It is expected that faint and distant ($z_{\text{phot}} > 4$) objects will be observed at the 6-m BTA telescope.

Our spectroscopy of the selected X-ray candidates for distant quasars detected by an improved selection method based on publicly accessible SDSS and WISE photometric data

confirmed that more quasars than in the available catalogs could be found (Richards et al., 2015; DiPompeo et al., 2015). The discovery of one of the most distant selected X-ray quasars (3XMM J125329.4+305539 at $z_{\text{spec}} = 5.08$) proves this convincingly.

Apart from the new quasar 3XMM J125329.4+305539 the K16 catalog contains three more optically bright ($i' < 21$) quasars at $z_{\text{spec}} > 5$. The X-ray fluxes and luminosities of these four objects in the 0.5–2 keV energy band exceed 1.5×10^{-15} erg/s/cm² and 4×10^{44} erg/s, respectively. About 50 sq. deg. is covered with this or better sensitivity in the regions of the overlap between *3XMM-DR4* and *SDSS* (see Fig. 9 in Khorunzhev et al. 2016). Therefore, it is interesting to note that approximately the same ($\sim 3 \times 10^{-15}$ erg/s/cm²) limiting sensitivity must be achieved in the planned four-year sky survey by the eROSITA telescope onboard the SRG observatory near the ecliptic poles in a field of about 150 sq. deg. (Merloni et al., 2012). Consequently, it will be possible to detect several new optically bright quasars at $z > 5$ with an X-ray luminosity higher than $\sim 10^{45}$ erg/s in these fields. At the same time, the total number of quasars at $z > 5$ discovered by the eROSITA telescope near the ecliptic poles may turn out to be much greater (tens or even hundreds; Kolodzig et al. 2013), but most of them will most likely be fainter than the SDSS sensitivity threshold. Deeper optical surveys, for example, *PanSTARRS* (Hodapp et al. 2004) and the sky surveys conducted by the *Hyper Suprime-Cam* (Miyazaki et al., 2012) at the 8-m Subaru telescope, will be required for their identification. Note also that the *K16* catalog has no X-ray quasars or quasar candidates at $z > 5$ with fluxes higher than 10^{-14} erg/s/cm² (corresponds to the mean all-sky sensitivity of the four-year eROSITA survey), i.e., a 0.5–2 keV luminosity higher than $\sim 3 \times 10^{45}$ erg/s in a field of $\simeq 250$ кв. град. This is consistent with the predictions made by Georgakakis et al. (2015) based on their model of the X-ray luminosity function for quasars at $3 < z < 5$. Consequently, one might expect no more than ~ 500 optically bright quasars at $z > 5$ with a luminosity higher than 3×10^{45} erg/s (0.5–2 keV) to be found in the eROSITA survey.

Our quasar spectra demonstrate the unique capabilities of the new ADAM spectrograph installed on the AZT-33IK telescope at the Sayan Solar Observatory. The ADAM spectrograph allows the spectra of objects with an apparent

magnitude $R \sim 19.5$ to be taken with an exposure time of 30 min. If necessary and under good weather conditions, a magnitude $I \sim 21$ can be reached with an exposure time of two hours. The ADAM spectrograph is planned to be one of the instruments for the optical support of the SRG project (Merloni et al., 2012; Pavlinsky et al., 2011).

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Table 1. Redshifts for the quasi-random spectroscopic sample

Name 3XMM	Date	RA	DEC	OBJID SDSS	$F_{0.5-2}^{-14}$	i'_{PSF}	z_{phot}	z_{spec}	QF	$z_{\text{phot } D15}$	$z_{\text{phot } R15}$	$L_{0.5-2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
J025459.8+192343	2015/10/13	43.7490	19.3957	1237673283585769514	1.448	19.17	2.60	2.81	*1			44.98
J062923.4+634935	2015/11/16	97.3468	63.8263	1237666462651646831	0.724	19.37	3.16	2.88	0	2.89	3.30	44.71
J074047.4+310856	2016/03/04	115.1979	31.1490	1237654627323216286	0.687	19.36	2.88	3.04	1	2.98	2.92	44.74
J074405.8+284354	2016/03/07	116.0246	28.7321	1237657119477924495	2.213	20.29	3.46		1			
J091740.4+161412	2016/03/09	139.4182	16.2366	1237667782815777585	0.412	20.27	3.42	3.51	1	3.46	3.45	44.67
J103148.9+584418	2015/11/16	157.9533	58.7395	1237655368745222588	0.492	19.60	3.33	3.62	0	3.60		44.78
J103901.4+643335	2016/03/05	159.7552	64.5593	1237651271895941447	0.332	20.55	4.01	4.08	1			44.73
J110518.4+250027	2016/02/04	166.3267	25.0085	1237667551956435181	0.377	19.95	3.21	3.56	1	3.51		44.64
J114529.7+024647	2016/03/04	176.3740	2.7799	1237654030330691765	0.569	19.01	2.85	2.68	0	2.72		44.52
J120641.1+651138	2016/02/05	181.6706	65.1941	1237651066815709744	0.178	19.53	3.34	3.47	0		3.45	44.29
J124232.3+141729	2016/03/10	190.6350	14.2914	1237662524694528017	0.517	18.39	2.82		1	1.91		
J125329.4+305539	2016/03/09	193.3721	30.9277	1237667255629579190	0.155	20.99	4.64	5.08	0			44.62
J131213.0+352347	2016/03/07	198.0539	35.3966	1237665026520318032	0.029	20.52	4.92		1	5.15		
J133200.0+503613	2016/02/05	202.9998	50.6037	1237662301357736036	0.776	19.59	3.78	3.83	1	3.93		45.03
J135538.5+383210	2016/03/08	208.9105	38.5361	1237662226223071466	0.395	19.23	2.90	2.86	1		2.97	44.43
J141625.4+361901	2016/04/07	214.1057	36.3162	1237662225151361223	1.573	19.86	3.33		1			
J151633.3+071039	2016/03/05	229.1385	7.1777	1237662237485564867	0.375	20.00	3.75	3.81	1	3.90		44.71
J215240.0+140206	2015/10/13	328.1669	14.0351	1237678601291760405	2.155	19.45	3.15	2.17	0	2.38		44.88
J234214.1+303606	2015/09/18	355.5590	30.6017	1237666183498039666	0.799	19.92	3.20	3.37	0	3.42		44.91
J122004.8+291304		185.0209	29.2179	1237665440975159694	0.279	20.73	3.38	0.002	*2			
J172014.1+264712		260.0592	26.7864	1237655501891110649	0.436	20.96	4.21	0.338	*3			

Table 1. Name — is the name in 3XMM-DR4 (3XMMJ...), Date — year/month/day when the first spectrum of the object was taken, RA is the right ascension, DEC is the declination, OBJID SDSS is the unique number in the photometric SDSS catalog, $F_{0.5-2}^{-14}$ is the 0.5–2 keV X-ray flux (erg/s/cm²) normalized to 10^{−14}, i' is the apparent magnitude in the SDSS i' band (AB, PSF), z_{phot} is the photometric redshift in the *K16* catalog, z_{spec} is the spectroscopic redshift, QF is the quality flag for z_{spec} (0 marks the redshift measured from several lines, 1 marks the redshift determined from only one *Ly*α line, *1 means that the object does not enter into the *K16* catalog, *2 means that the object is a globular cluster in a nearby galaxy Liu (2011); Usher et al. (2012), *3 means that the object is a galaxy (Owers et al., 2011)), $z_{\text{phot } D15}$ is the photometric redshift (PEAKZ) in the catalog by (DiPompeo et al., 2015), $z_{\text{phot } R15}$ is the photometric redshift (ZPHOTBEST) in the catalog by (Richards et al., 2015). $L_{0.5-2}$ — is the common logarithm of the 0.5–2 keV X-ray luminosity

Fig. 3. Spectra of 19 quasar candidates (including 3XMM J025459.8+192343 that does not enter into the final version of the *K16* catalog) taken with the ADAM spectrograph at the AZT-33IK telescope or (only 3XMM J125329.4+305539) with the SCORPIO spectrograph at the BTA telescope. For 3XMM J062923.4+634935 the horizontal line with marks indicates the set of absorption lines in the cloud of intergalactic gas at $z_{\text{spec}} \simeq 0.17$: $\lambda_{H\beta 4861} = 5696\text{\AA}$, $\lambda_{MgI5175} = 6077\text{\AA}$, $\lambda_{NaI5891} = 6895\text{\AA}$. The neighboring spectral channels were binned by two along the wavelength axis.

